

Claims

- [c1] A method of ionizing a liquid propellant, said method comprising the steps of:
- (a) applying an electrical charge to a showerhead;
 - (b) delivering a liquid propellant under pressure into a chamber defined within said showerhead; and
 - (c) emitting said liquid propellant under pressure through a plurality of micro-nozzles interspaced within the face of said showerhead to create a plurality of jets that collectively produce an electrospray having charged particles.
- [c2] An ionization method according to claim 1, wherein step (a) is accomplished with a power source selected from the group consisting of a direct-current electrical power source and an alternating-current electrical power source.
- [c3] An ionization method according to claim 1, wherein said showerhead comprises electrically conductive material.
- [c4] An ionization method according to claim 1, wherein said showerhead has an electrically conductive face and an electrically insulative layer substantially coating said

face, and each of said micro-nozzles is defined through both said electrically conductive face and said electrically insulative layer.

- [c5] An ionization method according to claim 1, wherein said showerhead has a face, and said micro-nozzles are substantially evenly spaced apart within said face.
- [c6] An ionization method according to claim 1, wherein said liquid propellant comprises an electrically conductive solution having a conductivity of at least 1 siemen per meter.
- [c7] An ionization method according to claim 1, wherein said liquid propellant comprises an electrolyte.
- [c8] An ionization method according to claim 1, wherein said liquid propellant is substantially inert.
- [c9] An ionization method according to claim 1, wherein said liquid propellant comprises salt water.
- [c10] An ionization method according to claim 1, wherein said liquid propellant comprises a tributyl phosphate solution.
- [c11] An ionization method according to claim 1, wherein said liquid propellant comprises a liquid metal selected from the group consisting of lithium and mercury.

- [c12] An ionization method according to claim 1, wherein each of said micro-nozzles has an inner surface that is substantially convergent.
- [c13] An ionization method according to claim 12, wherein said inner surface of each of said micro-nozzles has a shape resembling a structure selected from the group consisting of a cone and a frustum.
- [c14] An ionization method according to claim 12, wherein said inner surface of each of said micro-nozzles has a shape resembling a Taylor cone.
- [c15] An ionization method according to claim 12, wherein each of said micro-nozzles has a tip outlet with an inner diameter of less than about 10 micrometers.
- [c16] An ionization method according to claim 12, wherein each of said micro-nozzles has a tip outlet with an inner diameter of less than about 100 nanometers.
- [c17] An ionization method according to claim 1, wherein said electrospray comprises charged particles selected from the group consisting of charged droplets, individual ions, solvated ions, solvent molecules, and mixtures thereof.
- [c18] An ionization method according to claim 1, said method

further comprising the step of heating said liquid propellant to thereby elevate and maintain the temperature of said liquid propellant above the characteristic freezing point of said liquid propellant in a vacuum.

- [c19] A showerhead comprising:
an enclosure having an outer wall, a chamber defined within said outer wall, and an inlet defined through said outer wall; and
a plurality of micro-nozzles, collectively interspaced within said outer wall, for providing fluid communication between said chamber and the outside of said showerhead;
wherein each of said micro-nozzles has an inner surface that is substantially convergent.
- [c20] A showerhead according to claim 19, wherein said outer wall comprises electrically conductive material.
- [c21] A showerhead according to claim 19, wherein said showerhead has an electrically conductive face and an electrically insulative layer substantially coating said face, and each of said micro-nozzles is defined through both said electrically conductive face and said electrically insulative layer.
- [c22] A showerhead according to claim 19, wherein said show-

erhead has a face, and said micro-nozzles are substantially evenly spaced apart within said face.

[c23] A showerhead according to claim 19, wherein said inner surface of each of said micro-nozzles has a shape resembling a structure selected from the group consisting of a cone and a frustum.

[c24] A showerhead according to claim 19, wherein said inner surface of each of said micro-nozzles has a shape resembling a Taylor cone.

[c25] A showerhead according to claim 19, wherein each of said micro-nozzles has a tip outlet with an inner diameter of less than about 10 micrometers.

[c26] A showerhead according to claim 19, wherein each of said micro-nozzles has a tip outlet with an inner diameter of less than about 100 nanometers.

[c27] An electric thruster comprising:
a showerhead having an inlet and a plurality of micro-nozzles;
a reservoir for supplying propellant to said showerhead via said inlet;
means for accelerating charged particles; and
a power source connected to said showerhead and said accelerating means;

whereby said propellant is emitted under pressure from said micro-nozzles to produce an electrospray having charged particles, and said charged particles of said electrospray are accelerated by said accelerating means to produce thrust.

[c28] An electric thruster according to claim 27, wherein each of said micro-nozzles has an inner surface that is substantially convergent.

[c29] An electric thruster according to claim 28, wherein said inner surface of each of said micro-nozzles has a shape resembling a Taylor cone.

[c30] An electric thruster according to claim 28, wherein each of said micro-nozzles has a tip outlet with an inner diameter of less than about 10 micrometers.

[c31] An electric thruster according to claim 27, wherein said reservoir comprises at least one pressurized tank.

[c32] An electric thruster according to claim 27, wherein said accelerating means comprises a matching showerhead and a magnetic field generator.

[c33] An electric thruster according to claim 27, wherein said accelerating means comprises a planar structure selected from the group consisting of a grid, a hole-riddled plate,

and a screen.

[c34] An electric thruster according to claim 27, wherein said power source is selected from the group consisting of a direct-current electrical power source and an alternating-current electrical power source.

[c35] An electromagnetic thruster comprising:
two showerheads, at least partially facing each other and arranged to cooperatively define a gap, each having an inlet and a plurality of micro-nozzles;
a reservoir for supplying propellant to said showerheads via each said inlet;
a power source, connected to said showerheads, for creating an electric field in said gap; and
a magnetic field generator for creating a magnetic field in said gap;
whereby said propellant is emitted under pressure from said micro-nozzles to produce an electrospray having charged particles in said gap, said electric field and said magnetic field cooperatively induce a Lorentz force, and said charged particles are accelerated by said Lorentz force to produce thrust.

[c36] An electromagnetic thruster according to claim 35, wherein each of said micro-nozzles has an inner surface that is substantially convergent.

- [c37] An electromagnetic thruster according to claim 36, wherein said inner surface of each of said micro-nozzles has a shape resembling a Taylor cone.
- [c38] An electromagnetic thruster according to claim 36, wherein each of said micro-nozzles has a tip outlet with an inner diameter of less than about 10 micrometers.
- [c39] An electromagnetic thruster according to claim 35, wherein said reservoir comprises two pressurized tanks, and each of said pressurized tanks is dedicated to supplying propellant to a different one of said two shower-heads.
- [c40] An electromagnetic thruster according to claim 35, wherein said power source is selected from the group consisting of a direct-current electrical power source and an alternating-current electrical power source.
- [c41] An electromagnetic thruster according to claim 35, wherein said magnetic field generator comprises at least one magnetic solenoid.
- [c42] An electromagnetic thruster according to claim 35, wherein the direction of said magnetic field is substantially perpendicular to the direction of said electric field.
- [c43] An electrostatic thruster comprising:

a showerhead having an inlet and a plurality of micro-nozzles;
a reservoir for supplying propellant to said showerhead via said inlet;
a substantially planar structure, at least partially facing said showerhead and arranged therewith to cooperatively define a gap, having a plurality of holes defined therethrough; and
a power source, connected to said showerhead and said planar structure, for creating an electric field in said gap; whereby said propellant is emitted under pressure from said micro-nozzles to produce an electrospray having charged particles in said gap, and said charged particles are electrostatically accelerated across said gap and through said holes of said planar structure to produce thrust.

[c44] An electrostatic thruster according to claim 43, wherein each of said micro-nozzles has an inner surface that is substantially convergent.

[c45] An electrostatic thruster according to claim 44, wherein said inner surface of each of said micro-nozzles has a shape resembling a Taylor cone.

[c46] An electrostatic thruster according to claim 44, wherein each of said micro-nozzles has a tip outlet with an inner

diameter of less than about 10 micrometers.

- [c47] An electrostatic thruster according to claim 43, wherein said reservoir comprises a pressurized tank.
- [c48] An electrostatic thruster according to claim 43, wherein said planar structure is selected from the group consisting of a grid, a hole-riddled plate, and a screen.
- [c49] An electrostatic thruster according to claim 43, wherein said power source is selected from the group consisting of a direct-current electrical power source and an alternating-current electrical power source.